

A-level PHYSICS (7408/3A)

Paper 3 – Section A

Specimen 2014

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- a pencil
- a ruler
- a calculator
- a data and formulae booklet
- a question paper / answer book for section B.

Instructions

- Answer **all** questions.
- Show **all** your working.
- The total time for both sections of this paper is 2 hours.

Information

- The maximum mark for this section is 45.

Please write clearly, in block capitals, to allow character computer recognition.

Centre number

Candidate number

Surname

Forename(s)

Candidate signature

There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED**

Section A

Answer **all** question(s) in this section.

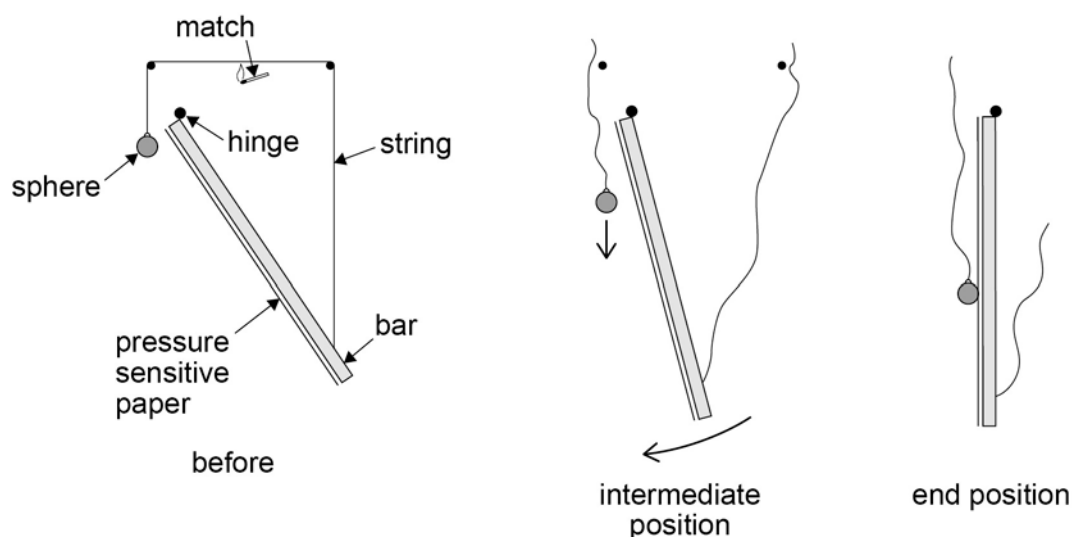
0 1

This question is about measuring the acceleration of free fall g .

A student undertakes an experiment to measure the acceleration of free fall.

Figure 1 shows a steel sphere attached by a string to a steel bar. The bar is hinged at the top and acts as a pendulum. When the string is burnt through with a match, the sphere falls vertically from rest and the bar swings clockwise. As the bar reaches the vertical position, the sphere hits it and makes a mark on a sheet of pressure-sensitive paper that is attached to the bar.

Figure 1



The student needs to measure the distance d fallen by the sphere in the time t taken for the bar to reach the vertical position.

To measure d the student marks the initial position of the sphere on the paper. The student then measures the distance between the initial mark and the mark made by the sphere after falling.

To measure t the student sets the bar swinging without the string attached and determines the time for the bar to swing through 10 small-angle oscillations.

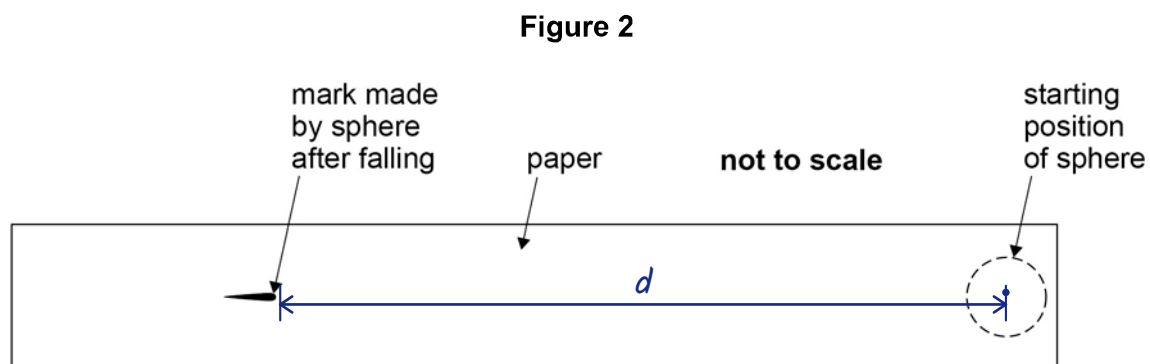
Question 1 continues on the next page

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- 0 1 . 1** **Figure 2** shows the strip of paper after it has been removed from the bar. The initial position of the sphere and the final mark are shown.

Mark on **Figure 2** the distance that the student should measure in order to determine d .

[1 mark]



- 0 1 . 2** The student repeats the procedure several times.

Data for the experiment is shown in **Table 1**.

Table 1

d / m
0.752
0.758
0.746
0.701
0.772
0.769

Time for bar to swing through 10 oscillations as measured by a stop clock = 15.7 s

Calculate the time for one oscillation and hence the time t for the bar to reach the vertical position.

[1 mark]

Period $T = 15.7 \div 10 = 1.57 \text{ s}$

Bar reaches vertical after a quarter of an oscillation:

$t = T \div 4 = 1.57 \div 4 = 0.393 \text{ s}$

time 0.393 s

- 0 1 . 3** Determine the percentage uncertainty in the time t suggested by the precision of the recorded data.

[2 marks]

Uncertainty in 10 oscillations = ± 0.1 s (precision of 15.7 s)

% uncertainty = $0.1 \div 15.7 \times 100 = 0.64\%$

t is $1/4$ of T , so it has the same % uncertainty = 0.64%

uncertainty = 0.64 %

- 0 1 . 4** Use the data from **Table 1** to calculate a value for d .

[2 marks]

0.701 m is anomalous, so it is left out of the mean

$d = (0.752 + 0.758 + 0.746 + 0.772 + 0.769) \div 5$

$d = 3.797 \div 5 = 0.759$ m

$d =$ 0.759 m

- 0 1 . 5** Calculate the absolute uncertainty in your value of d .

[1 mark]

Range = $0.772 - 0.746 = 0.026$ m

Absolute uncertainty = half the range = $0.026 \div 2 = 0.013$ m

uncertainty = 0.013 m

- 0 1 . 6** Determine a value for g and the absolute uncertainty in g .

[3 marks]

$d = \frac{1}{2}gt^2$, so $g = 2d \div t^2 = 2 \times 0.759 \div 0.393^2 = 9.83$ m s⁻²

% uncertainty in $d = 0.013 \div 0.759 \times 100 = 1.7\%$

Total % uncertainty = $1.7 + 2 \times 0.64 = 3.0\%$

Absolute uncertainty = $0.030 \times 9.83 = 0.30$ m s⁻²

$g =$ 9.8 m s⁻²

uncertainty = 0.3 m s⁻²

Turn over ►

0 1 . 7 Discuss **one** change that could be made to reduce the uncertainty in the experiment.

[2 marks]

Time more oscillations, e.g. 50 instead of 10. The ± 0.1 s uncertainty is then a smaller fraction of the total time measured, so this reduces the percentage uncertainty in the timing (in T and t).

0 1 . 8 The student modifies the experiment by progressively shortening the bar so that the time for an oscillation becomes shorter. The student collects data of distance fallen s and corresponding times t over a range of times.

Suggest, giving a clear explanation, how these data should be analysed to obtain a value for g .

[3 marks]

The sphere falls from rest, so $s = \frac{1}{2}gt^2$ ($s \propto t^2$).

Plot a graph of s (y-axis) against t^2 (x-axis), which should be a straight line through the origin.

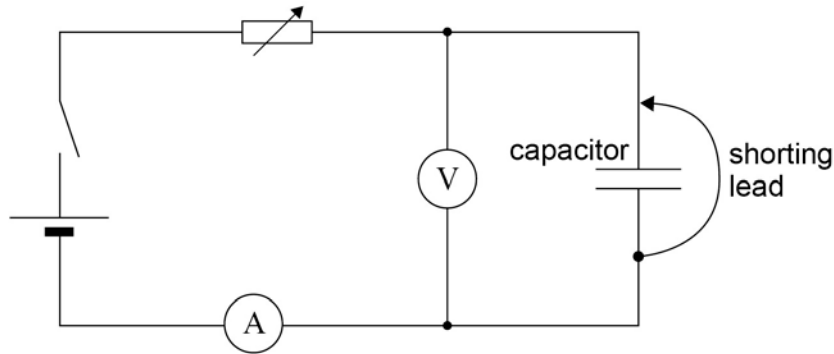
Calculate the gradient of the line using a large triangle. The gradient is $g/2$, so $g = 2 \times \text{gradient}$.

0 2

This question is about capacitor charging and discharging.

A student designs an experiment to charge a capacitor using a constant current. **Figure 3** shows the circuit the student designed to allow charge to flow onto a capacitor that has been initially discharged.

Figure 3



The student begins the experiment with the shorting lead connected across the capacitor as in **Figure 3**. The variable resistor is then adjusted to give a suitable ammeter reading. The shorting lead is removed so that the capacitor begins to charge. At the same instant, the stop clock is started.

The student intends to measure the potential difference (pd) across the capacitor at 10 s intervals while adjusting the variable resistor to keep the charging current constant.

The power supply has an emf of 6.0 V and negligible internal resistance. The capacitor has a capacitance of 680 μF . The variable resistor has a maximum resistance of 100 k Ω .

0 2 . 1

The student chooses a digital voltmeter for the experiment. A digital voltmeter has a very high resistance.

Explain why it is important to use a voltmeter with very high resistance.

[1 mark]

So that negligible current flows through the voltmeter: the capacitor must not lose charge through the meter, so all the charge flows onto the capacitor.

Question 2 continues on page 9

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ANSWER IN THE SPACES PROVIDED**

- 0 2 . 2** Suggest **one** advantage of using an analogue ammeter rather than a digital ammeter for this experiment.

[1 mark]

The position of the needle on the scale can be marked, so it is easier to see quickly when the current changes and to keep it constant.

- 0 2 . 3** Suggest a suitable full scale deflection for an analogue ammeter to be used in the experiment.

[2 marks]

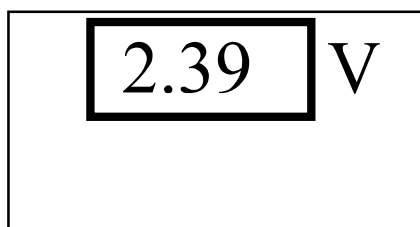
Minimum current (variable resistor at 100 kΩ):

$$I = V \div R = 6.0 \div 100\,000 = 60.0\,\mu\text{A}$$

So use 100 μA (or 200 μA) full scale, for a large deflection

full scale deflection = 100 μA

- 0 2 . 4** The diagram shows the reading on the voltmeter at one instant during the experiment. The manufacturer gives the uncertainty in the meter reading as 2%.



Calculate the absolute uncertainty in this reading.

[1 mark]

$$\begin{aligned} \text{Uncertainty} &= 2\% \text{ of } 2.39\,\text{V} = 0.02 \times 2.39 \\ &= 0.0478\,\text{V} \approx 0.05\,\text{V} \end{aligned}$$

uncertainty = 0.05 V

Question 2 continues on the next page

Turn over ►

- 0 2 . 5** Determine the number of different readings the student will be able to take before the capacitor becomes fully charged.

[3 marks]

$$\text{Total charge } Q = CV = 680 \times 10^{-6} \times 6.0 = 4.08 \times 10^{-3} \text{ C}$$

Current is at least $60.0 \mu\text{A}$, so time to charge fully:

$$t = Q \div I = 4.08 \times 10^{-3} \div 60.0 \times 10^{-6} = 68 \text{ s}$$

Readings at 10, 20, 30, 40, 50, 60 s, so 6 readings

number = 6

- 0 2 . 6** The experiment is performed with a capacitor of nominal value $680 \mu\text{F}$ and a manufacturing tolerance of $\pm 5\%$. In this experiment the charging current is maintained at $65 \mu\text{A}$. The data from the experiment produces a straight-line graph for the variation of pd with time. This shows that the pd across the capacitor increases at a rate of 98 mV s^{-1} .

Calculate the capacitance of the capacitor.

[2 marks]

$$Q = It \text{ and } Q = CV, \text{ so } I = C \times \Delta V / \Delta t$$

$$C = I \div (\Delta V / \Delta t) = 65 \times 10^{-6} \div 0.098 = 6.63 \times 10^{-4} \text{ F}$$

capacitance = 660 μF

- 0 2 . 7** Deduce whether the capacitor is within the manufacturer's tolerance.

[1 mark]

Yes: $680 \mu\text{F} \pm 5\%$ is $646 \mu\text{F}$ to $714 \mu\text{F}$, and $660 \mu\text{F}$ lies in this range (it is 97.5% of $680 \mu\text{F}$).

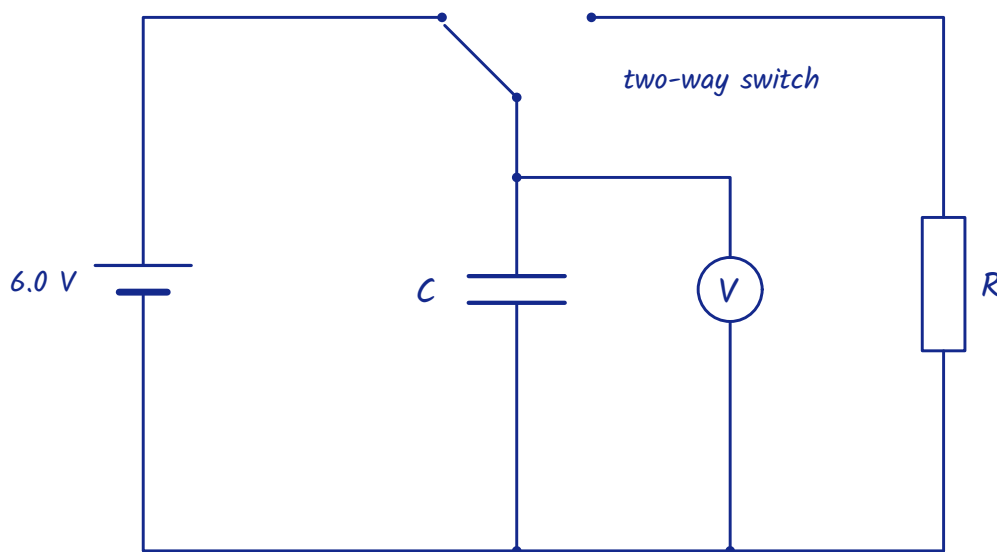
0 2 . 8

The student decides to confirm the value of the capacitance by first determining the time constant of the circuit when the capacitor **discharges** through a **fixed** resistor.

Describe an experiment to do this. Include in your answer:

- a circuit diagram
- an outline of a procedure
- an explanation of how you would use the data to determine the time constant.

[4 marks]



Charge the capacitor C by connecting the switch to the battery. Then move the switch to R and start the stop clock at the same instant, so C discharges through the fixed resistor R .

Record the pd V across C every 5 s (or 10 s) until V is small (or use a data logger to record V).

Plot a graph of $\ln V$ against time t . Since $V = V_0 e^{-t/RC}$, $\ln V = \ln V_0 - t/RC$, so the graph is a straight line with gradient $-1/RC$.

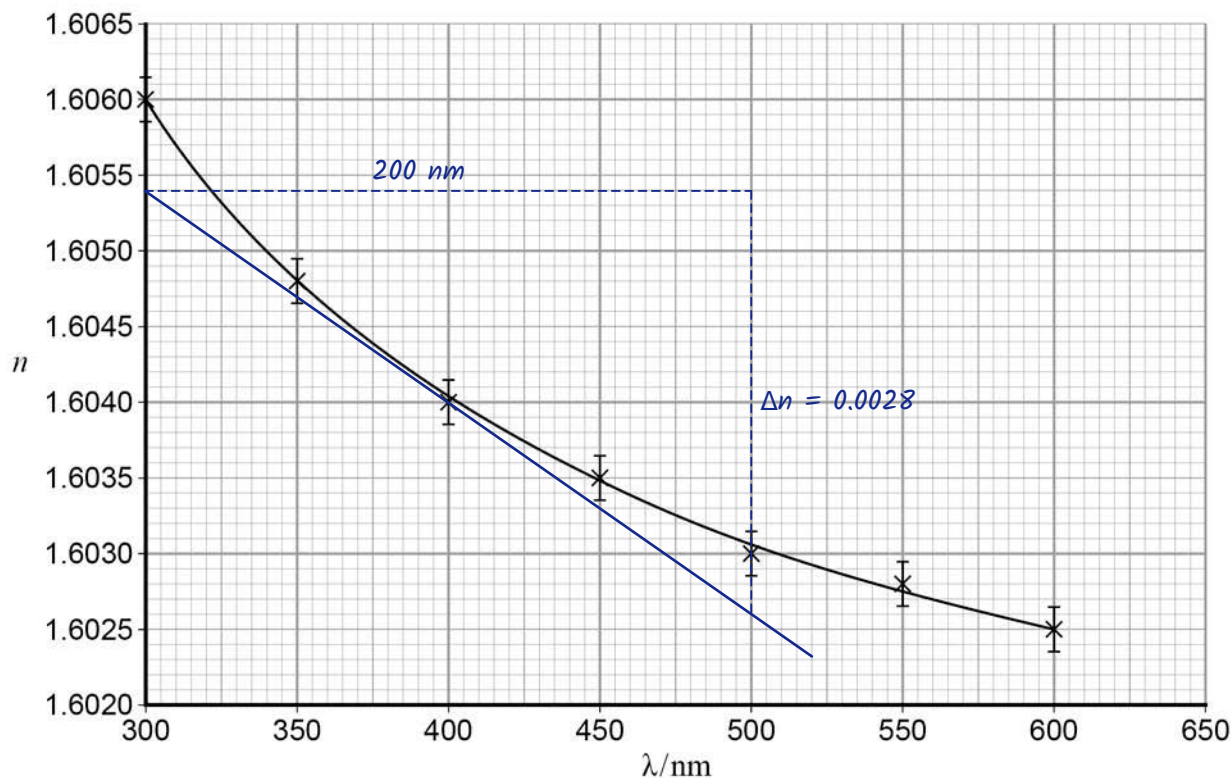
So the time constant $RC = -1 \div \text{gradient}$ (then $C = \text{time constant} \div R$).

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0 3

Figure 4 shows how the refractive index n of a type of glass varies with the wavelength of light λ passing through the glass. The data for plotting the graph were determined by experiment.

Figure 4



0 3

. 1

A student says that **Figure 4** resembles that of the decay of radioactive atomic nuclei with time and that it shows half-life behaviour.

Comment on whether the student is correct.

[1 mark]

Not correct. The changes in n halve every 100 nm (0.0020, 0.0010,

0.0005), but n itself does not halve every interval:

the graph has a false origin for n , so this is not half-life behaviour.

- 0 3 . 2** The dispersion D of glass is defined as the rate of change of its refractive index with wavelength. At a particular wavelength $D = \frac{\Delta n}{\Delta \lambda}$.

Determine D at a wavelength of 400 nm. State an appropriate unit for your answer.

[3 marks]

Tangent drawn to the curve at 400 nm (on Figure 4):

points (300 nm, 1.6054) and (500 nm, 1.6026)

$$D = \Delta n / \Delta \lambda = (1.6026 - 1.6054) \div (500 - 300) \times 10^{-9}$$

$$D = -0.0028 \div 2.00 \times 10^{-7} = -1.4 \times 10^4 \text{ m}^{-1}$$

D -1.4×10^4 unit m^{-1}

Question 3 continues on the next page

0 3 . 3 It is suggested that the relationship between n and λ is of the form

$$n = a + \frac{b}{\lambda^2}$$

where a and b are constants. The data plotted in **Figure 4** are given in **Table 2**.

Table 2

λ / nm	n	$1/\lambda^2 / 10^{12} \text{ m}^{-2}$		
300	1.6060	11.1		
350	1.6048	8.16		
400	1.6040	6.25		
450	1.6035	4.94		
500	1.6030	4.00		
550	1.6028	3.31		
600	1.6025	2.78		

You are to determine a using a graph of n against $\frac{1}{\lambda^2}$.

Make any calculations that you need to in order to plot your graph. The columns in **Table 2** are for you to use to calculate and tabulate the derived data that you need. You may not need all the columns.

[3 marks]

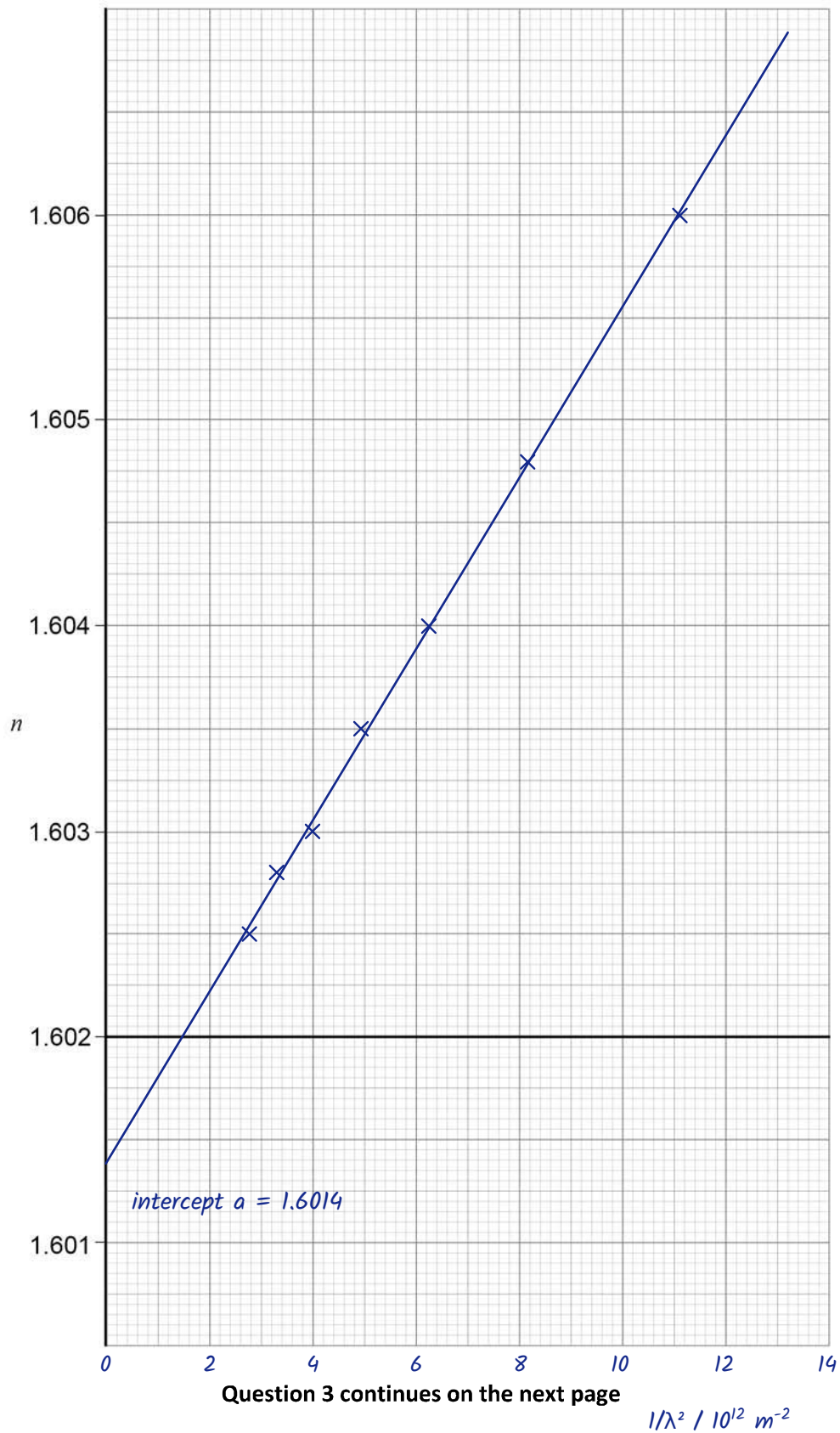
e.g. for 300 nm: $1/\lambda^2 = 1 \div (300 \times 10^{-9})^2 = 1.11 \times 10^{13} \text{ m}^{-2} = 11.1 \times 10^{12} \text{ m}^{-2}$

Gradient of n against $1/\lambda^2$ is b and the y -intercept is a .

0 3 . 4 Plot your graph on **Figure 5**. The values of n are provided on the y-axis.

[3 marks]

Figure 5



Turn over ►

0 3 . 5 Use your graph to determine a .

[1 mark]

$$a = y\text{-intercept} = 1.6014$$

0 3 . 6 State the significance of a .

[1 mark]

a is the refractive index of the glass at infinite (very long)
wavelength, since $1/\lambda^2 \rightarrow 0$.

0 3 . 7 Another suggestion for the relationship between n and λ is that

$$n = c\lambda^d$$

where c and d are constants.

Explain how d can be determined graphically. Do not attempt to carry out this analysis.

[3 marks]

Take logs of both sides: $\log n = \log c + d \log \lambda$.

Plot a graph of $\log n$ (y-axis) against $\log \lambda$ (x-axis), which should be
a straight line.

d is the gradient of this graph (and $\log c$ is the y-intercept).

END OF QUESTIONS